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Original article

Lateral meniscus allograft transplantation: Clinical and anatomic outcomes after arthroscopic implantation with tibial tunnels *versus* open implantation without tunnels

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ABSTRACT

Meniscus allograft transplantation (MAT) is used to treat patients with knee pain after total or subtotal meniscectomy. The graft can be inserted during open or arthroscopic surgery. The objectives are anatomic horn positioning and strong fixation to the bone and capsule of an appropriately sized graft.

Hypothesis: Arthroscopic MAT with trans-tibial bone fixation ensures better mid-term functional outcomes and limits allograft extrusion.

Patients and methods: We conducted a retrospective single-centre study of 23 consecutive patients who underwent MAT between 2001 and 2010. Among them, 11 had open surgery and anchoring of the horns without tunnels and 12 had arthroscopically-assisted surgery with bony fixation of the horns through trans-tibial tunnels. The two groups were comparable at baseline. Mean follow-up was 66.1 months. Post-operative outcomes were assessed using the IKDC score and KOOS, standard radiographs of both knees, and either magnetic resonance imaging or computed arthrotomography. We measured joint space narrowing, meniscal extrusion in the sagittal and coronal planes; and the degree of cartilage coverage by the graft using an index developed for this study.

Results: The overall failure rate was 17.4% (4/23, two cases each of complete and partial graft removal). Joint space narrowing increased by 28% *versus* the pre-operative value ($P = 0.009$). IKDC and KOOS values were not significantly different between the two groups. Absolute meniscus extrusion was greater in the arthroscopy group (4 mm *vs.* 3 mm, $P = 0.03$).

Discussion: Osteoarthritis of the transplanted compartment is unavoidable. Open surgery is associated with less meniscal extrusion. The clinical outcomes are independent from the technique used. Other factors require investigation, including graft rehabilitation, quality peripheral suturing, and intermeniscal ligament reconstruction.

Level of evidence: IV, retrospective study.

1. Introduction

Patients with a history of meniscectomy are at considerably increased risk for knee osteoarthritis compared to the general population [1] and develop the disease 10 to 20 years earlier than do patients with primary knee osteoarthritis. Total meniscectomy has now been virtually superseded by partial meniscectomy, meniscus repair, or surgical abstention with the goal of sparing the meniscus [2]. Nevertheless, large irreparable lesions may require total or subtotal meniscectomy. These procedures carry a risk of subsequent functional impairments and early knee osteoarthritis, most notably at the lateral compartment.

Meniscus allograft transplantation (MAT) may constitute a treatment option in young patients who have knee pain after meniscectomy but have not yet developed advanced osteoarthritis. Studies of MAT have shown good pain relief and functional improvements in the short, medium and long terms [3–5]. The anatomic objectives of MAT are to obtain anatomic horn positioning and strong fixation to the bone and capsule of a properly sized meniscus graft; meeting these objectives increases the likelihood of restoring joint homeostasis, thereby ensuring good knee function in the long term.

MAT was initially performed during open surgery, and graft fixation was confined to the periphery [6,7]. Techniques involving bone fixation of the horns using plugs inserted into tibial tunnels or a

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bony bridge [8] with no tibial tunnel (lateral grafts [9,10]) were developed. Arthroscopic techniques [11] were then devised on the theoretical grounds that soft-tissue lesions, scarring, and the risk of infection would be minimised; cartilage assessment improved and the meniscus horns positioned with greater accuracy.

Here, we compared two groups of patients who underwent lateral MAT. One group was managed by open surgery with fixation to the capsule but not to the bone and the other by arthroscopy-assisted surgery with trans-tibial and peripheral graft fixation. Our working hypothesis was that the arthroscopic technique with trans-tibial bony fixation produced better medium-term functional outcomes and minimised allograft extrusion.

2. Patients and methods

Between 2001 and 2010, two surgeons performed lateral MAT in 23 patients at the Versailles Hospital, Le Chesnay, France. Of the 23 patients, 11 underwent open MAT and 12 arthroscopy-assisted MAT (Table 1). Both groups were composed of consecutive patients.

At baseline, the two groups were comparable for all study variables except a history of varus osteotomy, which was noted for four patients in the open-surgery group *versus* none in the arthroscopy group.

2.1. Open surgery technique

A 3- to 4-cm lateral approach was used. The femoral attachments of the lateral collateral ligament and popliteus were identified. Osteotomy of these attachments was achieved by removing a bone slice about 1 cm in thickness. PDS 0 sutures were inserted through the graft at 3-mm intervals. The graft was then positioned into the compartment and the sutures used for fixation to the capsule (Fig. 1). At the end of the procedure, the popliteus/lateral collateral ligament complex was reattached using a 3.5-mm screw and a washer (Fig. 2).

2.2. Arthroscopy-assisted technique

After freshening of the meniscal wall, two guide wires were aimed at the tibial insertion sites of the anterior and posterior horns, using a ligamentoplasty aiming system. The tunnels were then created using 5-mm cannulated bits. Sutures were run through the tunnels and left for later use. A PDS loop was inserted through the popliteus. Both horns of the graft were tied using high-strength suture material, and a PDS 0 suture was inserted through the popliteal hiatus. After extension of the lateral approach, the graft was introduced by pulling on the sutures through the posterior horn and popliteus then secured using Fast-Fix (Smith & Nephew) at the posterior and middle graft segments. The anterior segment was not sutured to the capsule (Fig. 3). At the end of the procedure, both horns were sutured to the anterior aspect of the tibia using buttons.

Table 1
Comparison of the groups managed with open surgery and arthroscopy-assisted surgery for lateral meniscus allograft transplantation: baseline data and follow-up.

	Open surgery	Arthroscopy	*P* value
n	11	12	
Age, years	26.7	28	0.62
F/M	4/7	2/10	0.54
Time since meniscectomy, years	10.1	8.9	0.45
Cartilage lesions 0/1/2	3	1	0.57
Cartilage lesions 3/4	8	11	0.57
Joint space narrowing	24%	21%	0.96
History of osteotomy	4	0	
History of ligamentoplasty	1	2	0.59
Mean follow-up, months[a]	32	43	0.13
Lost to follow-up	1 (18 months)	3 (24 months)	0.59

n: number of patients; cartilage damage 0/1/2, numbers of patients without cartilage damage and with stage 1 or 2 cartilage damage; cartilage damage 3/4, numbers of patients with stage 3 or 4 cartilage damage.

[a] At first re-evaluation in the open-surgery group.

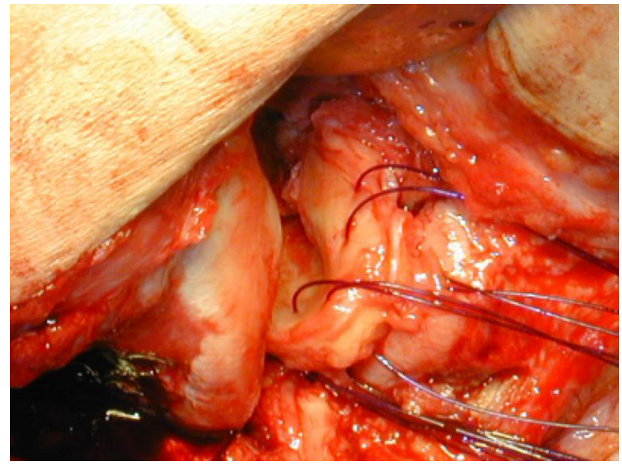

Fig. 1. The lateral collateral ligament/popliteus complex has been displaced, the graft is being introduced, and the PDS 0 sutures will be stitched to the capsule.

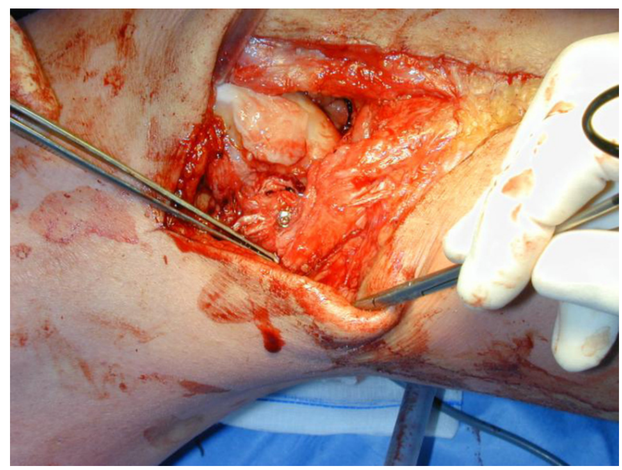

Fig. 2. At the end of the procedure, the osteotomy performed to detach the lateral collateral ligament/popliteus complex is re-implanted using a 3.5-mm screw.

2.3. Post-operative care

Patients in both groups wore a long-leg splint maintaining the knee in extension for one month. Flexion was not to exceed 90° during the next month and was subsequently unrestricted. Weight bearing was eliminated for six months then resumed gradually.

2.4. Post-operative assessments

Patients in the open-surgery group were re-evaluated in 2007, after a mean follow-up of 31.8 months. Patients in both groups were seen in 2012, after mean follow-up of 63.3 months (range, 22–122) overall, 73.3 months in the open-surgery group, and 43.4 months in the arthroscopy group. The two groups were compared using the data collected in the open-surgery group at the first re-evaluation, as the follow-up durations were then similar in the two groups.

Patients were assessed using the subjective and objective IKDC scores and the KOOS. Radiographs of both knees were obtained in the antero-posterior, lateral, and schuss views. Magnetic resonance

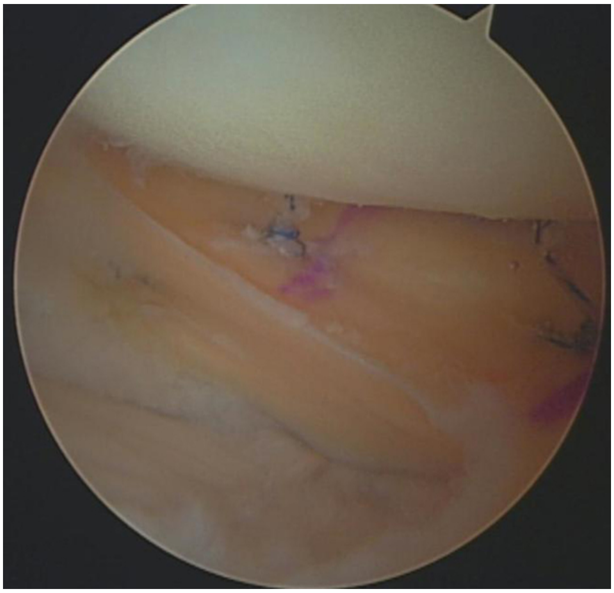

Fig. 3. Final arthroscopic appearance of an allograft. Fast-Fix was used for graft fixation to the residual meniscus wall and to the capsule.

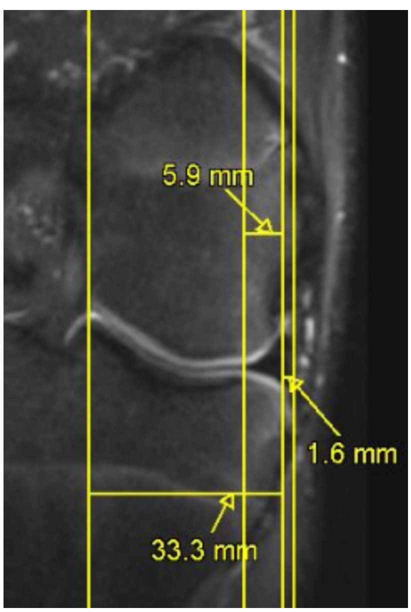

Fig. 4. Measurement of absolute meniscus extrusion (1.6 mm), relative meniscus extrusion (1.6/[1.6 + 5.9]), and the cartilage coverage index in the coronal plane (5.9/33.3) (normal meniscus).

imaging (MRI) or computed arthrotomography was performed to evaluate the graft. The coronal view through the centre of the tibio-femoral compartment was used to assess graft extrusion [12] as the value in millimetres of meniscus overhang beyond the lateral margin of the tibial plateau, without taking any osteophytes into account. On this same view, we computed the ratio of meniscus extrusion over total coronal graft size to obtain the percentage of extruded meniscus [13,14] (relative extrusion) (Fig. 4). On the sagittal view through the centre of the tibio-femoral compartment (identified by counting the number of views through that compartment then selecting the middle view), we measured extrusion of the anterior and posterior segments [15]. Anterior segment extrusion was the distance in millimetres between the anterior margin of the anterior segment and the anterior margin of the tibial cartilage. Posterior segment extrusion was the distance from the posterior

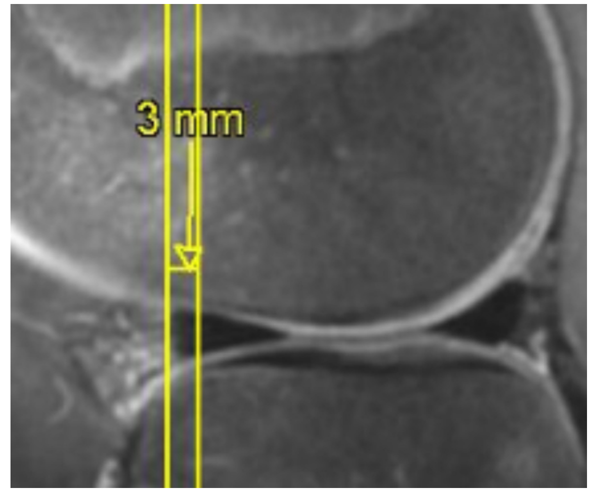

Fig. 5. Measurement of anterior segment extrusion (3 mm) (normal meniscus).

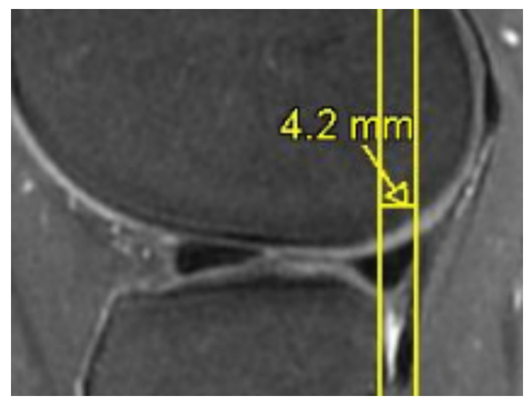

Fig. 6. Measurement of posterior segment extrusion (4.2 mm) (normal meniscus).

margin of the posterior segment and the posterior margin of the tibial cartilage (Figs. 5 and 6). These same sagittal and coronal views were used to measure the cartilage coverage index (CCI) as the percentage of tibial cartilage covered by the graft, which we computed by determining the ratio of tibial cartilage covered by the graft over the total tibial cartilage (Figs. 4 and 7). To our knowledge, the CCI has not been used previously.

To validate our measurements, we determined the same MRI extrusion parameters in the coronal and sagittal planes for the lateral meniscus of each of 25 young healthy patients. Inter-observer and intra-observer variability was assessed by having two senior surgeons obtain the measurements. All allograft MRI measurements were performed by the same senior surgeon, who had no role in any of the surgical procedures. Table 2 reports the intra-class coefficients (ICCs) for inter-observer and intra-observer variability. The interval between the two measurements used to assess intra-observer variability was three months.

2.5. Statistics

Descriptive statistics were computed for all the study data. Continuous variables were described as mean ± SD or median (interquartile range) depending on their distribution. Categorical variables were described as number (%).

Between-group comparisons of mean values were performed using Student's t test when the underlying assumptions were met and Fisher's nonparametric test otherwise. Similarly, to compare percentages, we chose the chi-square test and non-parametric

Table 2
Extrusion and cartilage coverage index (CCI) of the grafts compared to normal lateral menisci.

	Allografts (n = 16) MRI, n = 15 CT arthrogram, n = 1	Normal lateral menisci (n = 25)	P value	Inter-observer ICC	Intra-observer ICC
Meniscus extrusion	4.1	0.8	<0.0001	0.67	0.7
Meniscus extrusion, %	58.4	11.3	<0.0001	0.63	0.82
Coronal CCI	6	27.3	<0.0001	0.92	0.97
Anterior segment extrusion, mm	6	2	<0.0001	0.7	0.86
Posterior segment extrusion, mm	2.2	0.2	<0.0001	0.55	0.85
Sagittal CCI	27.1	53.1	<0.0001	0.64	0.93

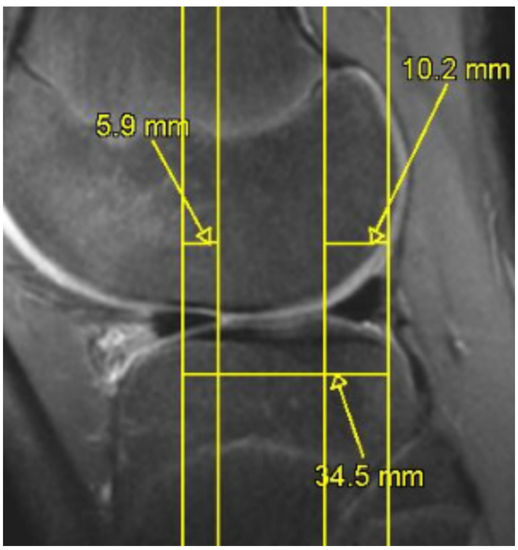

Fig. 7. Measurement of the cartilage coverage index (CCI) in the sagittal plane (5.9 + 10.2/34.5). This parameter reflects the proportion of cartilage covered by the graft (normal meniscus).

Wilcoxon test, respectively. Values of P were one-sided and considered significant when less than 0.05.

3. Results

3.1. Overall results

After a mean follow-up of 66.1 months (range, 22–122 months), graft failure (defined as partial or complete graft removal) had occurred in four (17.4%) patients (after mean 15 months).

Repeated meniscal suturing was required in two patients, after two years. None of the patients experienced knee stiffness or septic arthritis.

Median joint space narrowing increased from 24% preoperatively to 52% (P = 0.009) and tibio-femoral joint space narrowing worsened in 95% of patients. The median IKDC score was 65.5.

For all variables, absolute extrusion, relative extrusion, coronal CCI, and sagittal CCI differed significantly from those in healthy lateral menisci (Table 2).

3.2. Results in the open-surgery group

Over more than three years of follow-up, no further functional impairments developed in the open-surgery group. The medial IKDC score remained unchanged (69.3) and the median KOOS increased slightly, from 74.8 to 76.8. Absolute meniscus extrusion worsened significantly (P = 0.01). Joint space narrowing increased from 34 to 63% but the difference was not statistically significant (P = 0.06) (Table 3).

3.3. Comparison of results in the open-surgery and arthroscopy groups at first re-evaluation

Complete graft removal was required in one patient in each group. Partial graft removal was performed in two arthroscopy patients versus none of the open-surgery patients. We found no significant differences between the functional scores in the two groups (Table 4). Our structural evaluation showed that median absolute meniscus extrusion was greater in the arthroscopy group (4 mm *vs.* 3 mm, P = 0.03). None of the other parameters measuring extrusion or cartilage coverage differed significantly between the two groups.

4. Discussion

Cartilage damage progression was noted in the treated compartment despite allograft transplantation, with no significant difference between the two groups (P = 0.68). Overall, joint space narrowing worsened significantly, by 28% (P = 0.009) at last follow-up, and increased in 95% of the patients. Absolute meniscus extrusion increased significantly over time. A correlation between meniscus extrusion (most notably when >3 mm) and osteoarthritis was demonstrated in earlier studies [12]. The increased extrusion probably reflected osteoarthritis progression, although our small sample size (n = 11) prevented us from confirming this hypothesis (joint space narrowing increased from 34 to 63% (P = 0.06). The functional outcomes were satisfactory, with no deterioration over time.

Our clinical outcomes are similar to those reported previously in terms of both the functional results and the failure rate [4,5,16,17].

Absolute meniscal extrusion was more marked in the arthroscopy group (P = 0.03). This finding was not ascribable to greater progression of the cartilage damage (P = 0.68). We found no other significant differences between the two groups for the parameters measuring extrusion or cartilage coverage. This finding contradicts our working hypothesis that intra-tibial horn fixation decreases meniscus extrusion. De Coninck et al. [18] found less extrusion with arthroscopy than open surgery but after a much shorter follow-up of only one year. They also reported overall greater allograft extrusion compared to the contra-lateral normal meniscus. Possible explanations to the greater graft stability with open surgery may include a better match of graft position to normal anatomy, greater fixation stability with a larger number of stitches, or greater strength of PDS 0 stitches compared to Fast-Fix.

In the sagittal plane, extrusion occurred chiefly at the anterior segment, whereas posterior segment extrusion was limited (median values: anterior, 6 mm *vs.* 2 mm for normal menisci; posterior, 2.2 mm *vs.* 0.2 mm for normal menisci). Anterior extrusion

Table 3
Outcomes in the open-surgery group at the first and second re-evaluations.

	First re-evaluation	Second re-evaluation	*P* value
Follow-up, months	31.8	77.4	
Survival rate, %	91	91	
Partial graft removal rate, %	0	9	
Meniscus suture rate, %	9	18	
Objective IKDC	1A, 3B, 1C, 1D,	7B, 2D	
Subjective IKDC	69.5	69.5	1
KOOS symptoms	80.4	76.8	0.63
KOOS pain	84.7	88.9	1
KOOS activities of daily living	94	97	0.72
KOOS sports and recreation function	52.5	60	0.55
KOOS quality of life	62.5	61.7	0.76
Joint space narrowing, %	34	63	0.06
Meniscus extrusion, mm	3	4.3	0.01
Meniscus extrusion, %	63	60.6	0.67
% cartilage coverage, coronal	8.4	5	0.12
Anterior segment extrusion, mm	3	7.4	0.08
Posterior segment extrusion, mm	−1.3	1.4	0.83
% cartilage coverage, sagittal	25.9	26.3	0.49

Table 4
Comparison of the outcomes in the open surgery and arthroscopy groups.

	Open surgery	Arthroscopy	*P* value
n	11	12	
Follow-up, months	31.8	43.4	
Survival rate, %	91	92	1
Meniscus lesion rate, %	18.1	25	0.64
Meniscus suture rate, %	9	0	
Partial graft removal rate, %	0	16.6	
Joint space narrowing, %	34	55	0.68
Objective IKDC	1A, 3B, 1C, 1D,	7B, 2D	
Subjective IKDC	69.5	47.1	0.37
KOOS symptoms	80.4	50	0.63
KOOS pain	84.7	64	1
KOOS activities of daily living	94	69	0.72
KOOS sports and recreation function	52.5	30	0.55
KOOS quality of life	62.5	31.3	0.76
Meniscus extrusion, mm	3	4	0.03
Meniscus extrusion, %	63	52	0.09
% cartilage coverage, coronal	8.4	9	0.93
Anterior segment extrusion, mm	3	3.3	0.79
Posterior segment extrusion, mm	−1.3	2.35	0.09
% cartilage coverage, sagittal	25.9	28	0.56

resulted in decreased cartilage coverage (27.1% with the allografts *vs.* 53.1% for normal menisci).

Despite the smaller degree of absolute extrusion in the open-surgery group, we found no proof that open surgery was superior over arthroscopy in terms of the clinical outcomes. Koh et al. [19] and Verdonk et al. [20] underlined the absence of any correlation between meniscus extrusion and clinical outcomes. Furthermore, the clinical outcomes cannot be ascribed solely to the degree of extrusion, as graft recovery and pre-operative cartilage status are also major factors. Nevertheless, all the functional scores were better in the open-surgery group than in the arthroscopy group and, for some of these scores, the difference approached statistical significance ($P = 0.06$). The open-surgery technique is clearly superior over the arthroscopy technique and that our small sample size and resulting limited statistical power prevented us from demonstrating this point.

Extrusion occurs almost consistently regardless of the technique used. Graft extrusion always exceeds the normal extrusion seen in healthy knees and also exceeds the 3-mm cut-off considered to indicate an osteoarthritic process. In a study of native knees, Gale et al. [12] found a correlation between meniscus extrusion and tibio-femoral joint space narrowing. Bennett and Buckland-Wright [21] showed that tibio-femoral narrowing was due initially to cartilage wear and meniscus extrusion. Thus, allograft extrusion and the resulting cartilage exposure are probably ascribable to the progression of joint space narrowing over time.

In our study, there is no evidence that trans-tibial horn fixation produced better outcomes. Wajsfisz et al. [22] established the anatomic feasibility of arthroscopically-assisted lateral MAT in which horn fixation is achieved without tunnels, thereby sparing the bone stock. Abat et al. [23] found no evidence that a technique involving bone plugs was superior over absence of bone plugs.

Other factors may affect the development of meniscus graft extrusion. Excessive graft size has been incriminated [15]. Jang et al. [24–26] showed that decreasing graft size by 5% to ensure pre-tensioning of the allograft was associated with diminished extrusion. The lateral meniscus is not normally attached to the anterior capsule. Excessively tight stitches to secure the lateral graft to the anterior capsule may pull the graft forward, explaining the development of anterior extrusion contrasting with the limited degree of posterior extrusion. We no longer suture the anterior segment. The absence of inter-meniscal reconstruction may contribute to the anterior extrusion. The role for this ligament is unclear [27]. It does not connect the horns but instead extends from the middle of the anterior segment of the lateral meniscus to the anterior segment of the medial meniscus, thus closing the peripheral meniscal belt and possibly contributing to pre-tensioning of the anterior lateral meniscus. Reconstruction of this ligament is not performed in any of the available techniques.

Strengths of our study include the single-centre design with two surgeons and the accurate MRI evaluation of meniscus extrusion in the coronal and sagittal planes. We introduced a new criterion, the CCI, to evaluate the percentage of the graft that actually fulfils the shock-absorbing role of the meniscus. To improve measurement reproducibility, we deliberately measured all the parameters at the centre of the joint space, in contradistinction to previous studies (measurement of maximal extrusion as opposed to extrusion at the centre of the joint space).

The main limitations of our study are the small sample size and retrospective data collection. The pre-operative scores were not available and we were consequently unable to assess the degree of clinical improvement. The presence in the open-surgery group of four (36%) patients with a history of varus osteotomy *versus* none in the arthroscopy group may have biased the interpretation of the results. We were unable to obtain dynamic MRI scans to assess graft mobility during knee flexion.

5. Conclusion

The clinical outcomes in our patients are similar to those reported previously in both groups. Thus, horn fixation through intra-tibial tunnels during arthroscopy-assisted surgery did not improve the results. The outcomes were not influenced by the medium-term cartilage status. Joint space narrowing increased over time.

Absolute and relative graft extrusion occurred at the anterior and middle segments, resulting in exposure of the cartilage. This extrusion was less marked with the open-surgery technique.

Our findings fail to confirm our working hypothesis. Meniscus extrusion is not solely dependent on horn fixation, regardless of the technique used. Other factors that deserve further evaluation include the quality of peripheral suturing, whether or not the anterior segment of the lateral graft is sutured, and the role for the inter-meniscal ligament.

Disclosure of interest

P. Beaufils: occasional educational consultant for Smith & Nephew and Zimmer company.

B. Faivre, P. Boisrenoult, G. Lonjon, N. Pujol have no interest in relation with this article.

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